PASTEUR

AND

HIS WORK:

BEING A LECTURE DELIVERED BEFORE THE

WINDSOR AND ETON SCIENTIFIC SOCIETY,

On THURSDAY, DECEMBER 5th, 1889,

BY

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WINDSOR:

OXLEY AND SON, PRINTERS TO THE QUEEN, HIGH STREET.

1890.

THE latter half of the 19th century, now rapidly drawing to its close, will ever be associated with three great scientific doctrines, *firstly* the theory of the molecular structure of matter, *secondly* the theory of the conservation of energy, and *thirdly* the theory of evolution.

Each of these doctrines had been foreshadowed either by the philosophers of ancient Greece or by the naturalists of the 17th and 18th centuries, but it was reserved for our own epoch to convert these hypotheses into sound theory, and to show how by their means the vast array of isolated observations and partial generalizations, accumulated in past ages fall into an orderly and intelligible series of laws which control the visible world.

These three doctrines alone are sufficient to justify the assertion that our epoch can boast of achievements in the domain of natural science such as no other can show, and although we have been warned "not to prophecy unless we know," I think it will not be mere conceit on our part if we venture to doubt whether the next half century will be as fruitful in respect to such wide generalization, as the last.

In one of his books (Frondes Agrestes) Mr. Ruskin has written as follows: "It is ordained for our encouragement that every step we make in the more exalted range of science adds something also to its practical applicabilities"; and the truth of this becomes at once apparent if we glance at the unparalled development of every kind of scientific appliance which has gone hand in hand with the verification of the theories mentioned above.

If the times in which we live are remarkable for wide generalizations which enable us to fathom to some depth the natural laws which govern the universe in which we have our being, they are no less remarkable, and much more obviously so, for the extraordinary development of all kinds of machinery and scientific instruments, for the immense advance in all technical processes, and for the remarkable improvement in means of locomotion and intercommunication.

By the aid of highly sensitive photographic plates we can demonstrate the existence of stars, which are far beyond the range of the human eye even when aided by the most powerful telescopes, situated in the clearest atmospheres. Their position can be rigidly determined, and now that the spectroscope forms part of the equipment of every observatory, the astronomer can accurately analyse the substances which compose them. On our own globe the growth of knowledge of electricity has enabled us to communicate our ideas to the other side of the world in a few seconds, and our voices pass between places hundreds of miles apart in a few minutes.

Not only is space bridged over, and distance at a discount, but time has been forced to reveal her secrets. The past gives up her dead to the palœontologists, and he makes the dry bones to live. He re-constructs the extinct fauna and flora of the pre-historic earth, and the geologist gives us a picture of the birth and growth of worlds, whilst the mathematician calculates the length of day and time of the tide long before man made his debût on the terrestial globe. At the same time we can foretell with some degree of accuracy what will happen in the future. Physicists calculate the approximate date at which the sun's heat will give out, the weather forecasts are more accurate than the casual newspaper reader would suspect, and by means of the phonograph we are able to project our voices into what we may call the middle distance, and by its aid we may feel as sure as the unappreciated poet of to-day, that posterity will listen to our song.

In no department of science has a greater advance taken place than in the study of the infinitely little. The very existence of micro-organisms, the study of which has revolutionized the science of curative medicine, was unknown thirty years ago, and it is the growth of this study to which I wish to direct your attention this evening. In doing this I cannot take a better text than the life and work of Louis Pasteur, who though not a doctor, not even a veterinary surgeon, has done more to elucidate the causes of disease than any other living man.

As you pass along the Rue des Tanneurs, in the little town of Dôle, situated at the foot of the Jura, you notice a small house whose façade is ornamented by a plate bearing these words written in letters of gold—

HERE WAS BORN, LOUIS PASTEUR,
DECEMBER 27TH, 1822.

When he was two years old, his family, which consisted of his father, mother, and himself, moved to the neighbouring town of Arbois, where his father had bought a small tan-yard. In this small country town Pasteur passed his childhood and youth, attending the communal school, and repeating to his father every evening, the lessons he had learnt there during the day.

When still a boy his attention was directed to science, but it was not until 1843, when he entered the Ecole Normale at Paris (having secured the 4th place in the competitive entrance examination), that he was able to gratify his passion in this direction.

Here his taste for chemistry received full recognition, and under the guidance of the distinguished chemists Balard and Dumas, at that time professors at Paris, he made great progress in his favourite subject. Whilst still a student at the Ecole Normale, Pasteur commenced an investigation in the domain of molecular physics. His attention had been drawn to the behaviour of the crystals of certain salts of tartaric and para-tartaric acid with regard to their power of influencing the plane of polarization. It would be outside our province to consider in detail this piece of research, but I may mention that as a result of this series of investigations, Pasteur formulated the view that the ultimate molecule of the organic world differs from that of the inorganic by possessing the property of acting on polarized light. This view is, I believe, still held by Pasteur, though it has hitherto failed to meet with general acceptance.

In the midst of these researches he was nominated assistant to the professor of chemistry at Strasburg, and here he carried on his investigations with so much ardour, that on the morning of his marriage with the daughter of the Rector of the Strasburg Academy, it was found necessary to send a messenger round to the Laboratory to remind him of the ceremony about to take place in the neighbouring church.

About this time a German manufacturer of chemicals, drew Pasteur's attention to the fact that the contents of his vats of impure tartrate of lime dissolved in water, fermented when exposed to the summer sun. His solution became turbid, its chemical composition was altered, and the liquid swarmed with micro-organisms. With that marvellous intuition which is so characteristic of the man, Pasteur recognised that these micro-organisms were the cause and not the result of the decomposition, and for the first time established the existence of living ferments. Here for the first time we find Pasteur launched into those studies of fermentation and putrefaction which will make his name famous through all time. It is impossible to help speculating as to the results which are lost to the world through this deviation of Pasteur's from the field of those chemical physics to which he was so much attached, into the bye-ways of biology. Would he not have aided us in arriving at some understanding of the ultimate constitution of matter? Would he not have thrown much light on the obstruse but fascinating question of the difference between living and non-living material? But I think we are justified in saying that whatever the world has lost in respect to these recondite subjects has been more than counter-balanced by his brilliant researches into the causation and prevention of contagious disease.

At the age of thirty-two, Pasteur was nominated Dean of the Faculty of Science at Lille. This town is the centre of a large district whose population are employed in the manufacture of alcohol from beetroot and corn, and consequently afforded ample opportunity for the further study of fermentation.

Pasteur's view that fermentation is caused by a micro-organism, a microbe or germ, did not at first meet with recognition. The whole weight of authority was opposed to it. On the one hand the great German chemist Liebig held that fermentation was due to certain nitrogenous-substances in contact with the air, on the other hand Berzelius and his school maintained that it was caused by the presence of certain albuminoid substances in the fermenting fluid. Pasteur shewed that what these eminent chemists had considered to be ferments, was in reality the food of the ferments, the substances in fact which *were* fermented or broken up into simpler chemical compounds by the presence of the micro-organisms. His conclusions were much strengthened by the discovery which had been made shortly before by Cagniard-Latour and Schwann of the yeast cells, millions of which form the substance we know as yeast.

Pasteur next investigated the conditions under which milk turns sour, this is due to the formation in the milk of a quantity of lactic acid, and he was able to show that this also was brought about by the presence of a micro-organism which converts the sugar in milk into lactic acid just as the yeast cell splits up the sugar of the malt into alcohol and carbonic acid gas. Then he attacked butyric acid, a substance formed when butter becomes rancid, and which gives butter in this condition, its unpleasant flavour, this again he showed to be due to the presence of a germ, and whilst studying it he discovered a very remarkable physiological fact. Previous to these researches on the formation of butyric acid, it was believed that every form of living organism required free oxygen in order to live. This was one of the very few generalizations in Biology which was regarded almost in the light of an axiom; yet Pasteur broke it down. He shewed that not only could the germs producing butyric acid fermentation live without oxygen, but that the presence of this gas was positively harmful to them. It poisoned them. So that if a current of oxygen is passed through the vessel in which this fermentation is going on, the germs cease their work, fall to the bottom of the vessel and die; and the fermentation is arrested.

To this new class of organisms, capable of living without free oxygen, Pasteur gave the name of Anærobiotic, reserving the name Aerobiotic for those organisms which, like the higher plants and animals, cannot exist unless in the presence of free oxygen.

Pasteur next commenced an inquiry into the formation of vinegar from wine, and showed that this was due to the presence of minute bacterium, Mycoderma aceti, which acts upon the wine and turns it sour, just as the bacterium of the lactic acid fermentation turned milk sour. These investigations led him to enquire how it was that wine occasionally lost its flavour, and turned sour and sharp to the taste, when it was not intended to, and acquired characters the reverse of palatable. In some cases, those in which the wine became vinegary, the answer was found in the presence in the wine of the Mycoderma aceti, mentioned above, in other cases other germs were found, each of which caused some disease in the wine, accompanied by a loss of flavour. Fortunately these germs which cause so much havoc in the wine trade, are very susceptible to heat. By raising the temperature to 50°C. the germs are destroyed, and this without any injury to the flavour of the wine. In order to prove this, Pasteur in the year 1865, arranged an experiment on a very large scale. He brought together a committee, consisting of the most experienced wine tasters in France, with the object of testing wines which had been subjected to his treatment of heating. After repeated trials this committee declared that no difference was perceptible between the heated and non-heated wines, and indeed they found it impossible to say which of two bottles had been heated unless warned beforehand.

We cannot this evening go into further detail of the researches of Pasteur into the fermentation and diseases of wine and vinegar, which have done so much for industries supporting many of his countrymen. But in this relation two subjects occur which merit our attention.

Firstly, what is the origin of all these germs? They appear everywhere, they turn our milk sour, our butter rancid, and our wine vinegary. Where do they come from? Have they arisen spontaneously, or are they invariably derived from pre existing germs? The battle over this question, that of spontaneous generation, has been a long and bitter one, and it is profitless to review the arguments for and against it, the outcome of it, however, amounts to this: under existing conditions, at the present time, living matter does not proceed from non-living, but is invariably derived from pre-existing organisms. If a nutrient solution, in which germs are swarming, is once thoroughly sterilized by heating to such a temperature as will kill the germs, and then if the access of other germs be prevented by hermetically sealing the tube, or by a plug of cotton wool, which is an excellent filter for bacteria, no fresh fermentation will ever arise in the solution. The difficulty of arriving at this dogma has been much increased by the extraordinary faculty possessed by some germs of resisting for a long period of time exposure to high temperatures, *e.g.*, infusions made by soaking hay in water, have been known to withstand the sterilizing influence of eight hours boiling; but if proper precautions are taken, repeated experiment tends only to confirm the view that spontaneous generation does not take place at present.

The other side issue of Pasteur's researches in fermentation to which I would draw your attention, is that of putrefaction. This phenomenon is only the fermentation of certain organic substances, and is usually associated with an unpleasant smell. Dr. now Sir, Joseph Lister's attention had been drawn to Pasteur's experiments in the fermentation of milk, and it occurred to him that the putrefaction which so frequently sets in after amputations or other surgical operations, might be set up by the presence of bacteria. If this were so, operations conducted under circumstances inimical to the life of germs, ought not to be followed by mortification, which so frequently ended in the death of the patient.

In the month of March, 1865, at the Glasgow Infirmary, Lister performed his first operation under what is termed anti-septic treatment, that is, under conditions which precluded the admission of germs to the raw surface of the wound, whether from the air, or by the hands or instruments of the operator. These conditions are usually brought about by washing the hands and instruments in carbolic acid, and keeping a fine spray of the same liquid playing over the wound, etc., during the operation. The success of this treatment in reducing the death-rate from surgical fever was soon established, and this method of treatment which is necessarily associated with the most scrupulous cleanness, was soon adopted throughout the hospitals of the civilized world. Its invention and adoption are entirely English, and are probably the greatest achievement in preventive medicine that the last half century can show. In this branch of the healing art, Dr. Brudenell Carter says, "We stand absolutely alone, a few continental researches being of just sufficient value and importance to illustrate the height of our preeminence," but although this statement is true and extremely gratifying to our national pride, it would be unfair to forget that the immense gift to humanity, with which Lister's name must always be associated, was suggested by Pasteur's researches in the fermentation of milk.

We have now to pass to a new phase in the work of the great French biologist. Throughout large districts in the south of France, the inhabitants depend for their means of gaining a livelihood on the silk-worm culture. The care these insects require is well known to every schoolboy, but when silk-worms are kept for business and not for amusement, the anxiety is multiplied a hundred-fold. During the night you must be up to feed them, and to see that the temperature is neither too high or too low; the first question in the morning is not how are you? but how are the silk-worms? During the day you are occupied with gathering leaves for the food, and much care must be exercised to see that the leaves are not damp with rain or dew.

In spite of all the trouble taken to shield the silk-worms from harm, a terrible disaster befell the silk culture about the middle of the present century. The year 1849, had been a favourable one, the weather was good, the mulberry leaves were plentiful and not too damp, and the silk-worms digested well, yet many of the cultivations were unsuccessful and others failed completely. A plague had broken out amongst the silk-worms, and they sickened and died.

The symptoms of this mysterious disease varied a good deal; as a rule the silk-worms assumed a shiny appearance, and black spots arose under their skin, their appetite for food, usually so insatiable, failed; and the worms lost the power of movement and perished miserably.

The stage in the life history of the silk-worm, at which these symptoms appeared, varied extremely. Sometimes the eggs were sterile, at other times the worms would hatch out, but to die; again the worms would live through the first three moultings and would then sicken and die. Sometimes the cocoon were infected and no moth emerged, or the moth crept out only to become a victim to the disastrous epidemic.

At first, efforts were made to strengthen the brood by importing sound eggs from abroad, but the disease spread; Spain and Italy became infected, and eggs were fetched from Turkey, Greece, and the adjacent islands. These countries then caught the infection, and the French cultivators, sending farther afield, brought eggs from Syria and the Caucasus; even this resource failed them, when in the year 1864, every silk-growing region in the world was tainted, with the single exception of Japan.

The extent of the damage caused by the disease may be estimated from the fact that the weight of silk produced in France, fell in 12 years from 26,000,000 kilograms to 4,000,000, entailing a loss of £4,000,000, and involving the ruin of a large population. The French government was overwhelmed with requests for aid in what was rapidly becoming a grave national calamity, and they appointed a Commission to see what could be done. To this Commission, Dumas was appointed reporter, and it was at his suggestion that Pasteur was sent to investigate the cause of the disease.

Before Pasteur left Paris for the South in 1865, he had told Dumas, that he had never even handled a silkworm, and we may conclude that his mind was entirely free from any preconceived ideas as to the cause of the calamity. One thing, however, had struck him in looking through the mass of literature which had accumulated on the subject, and this was an observation made by two Italian naturalists, Filippi and Cornalia, in the year 1856. These observers had described certain minute corpuscles, visible only with the aid of a microscope, which swarmed in the bodies of the diseased worms. Pasteur, who had just completed his researches on the micro-organisms causing fermentation, was well equipped for the investigation of what proved to be another microbe. On the 6th of June he started for Alais, in the south of France, and in the evening of the same day, within a few hours of his arrival, he had proved the existence of the corpuscles of Filippi and Cornalia, and had shown them to the local authorities. From that moment commenced a series of experiments which were carried on during the summers of the succeeding five years. Experiments, which are now repeated in every physiological laboratory, but which were at that time new to science.

Pasteur showed that the germ—*Micrococcus ovatus*, or *bombycis*—swarmed in the bodies of the silk worms, that they were present in the excreta, and consequently got on to the mulberry leaves. He showed further that feeding healthy worms with food containing the germs, caused the disease, and consequently eating the infected leaves brought it on. He also showed that the disease could be inoculated through the skin, and that healthy worms were frequently so inoculated by the sharp claws of their comrades, on which some of the virus had settled, as they crawled over each other. One of the most important points Pasteur succeeded in proving was that the malady is transmitted through the egg, consequently, eggs laid by a diseased moth will produce infected larvæ, and eggs laid by a healthy moth will give rise to healthy larvæ, if the brood is carefully isolated. The knowledge of this fact has freed the country of the disease. All through the south of France, in the silk-worm districts, as soon as the moth has laid her eggs on the piece of linen provided for that purpose, she is pinned up with the cloth, and in the autumn and winter months, the women and children of the district are occupied in microscopically examining the body of the moth, crushed in a little water, for traces of the Micrococcus. If any are found, the eggs in the corresponding piece of linen are at once destroyed. By these means the disease is kept within control, and in certain regions has been stamped out.

Pasteur returned to Paris towards the end of 1868, having restored wealth to thousands threatened with ruin, and saved his country from a grave national calamity. Unfortunately the over-work of the last few years, and the incessant strain and anxiety when so much was at stake, proved too much for him, and in October, 1868, he was struck down with an attack of paralysis of the side; during this illness, fearing that matters were going unfavourably with him, and not expecting to recover, he dictated to his wife some last notes on the silk-worm disease, which was constantly occupying his thoughts.

At length he began to slowly mend, and ultimately recovered, although to this day he shows traces of this stroke in a marked lameness of the left side. In January, 1869, roused by the opposition of his detractors, Pasteur, although unable to drag himself about the room, started a second time for Alais, where he verified again his previous experiments. In spite of this verification, the French government still hesitated to declare itself officially in favour of his methods, and at this juncture the late Emperor stept in, and placed at Pasteur's disposition, the Villa Vicentina, near Triste, the property of the Prince Imperial. With great difficulty Pasteur travelled there, his health still being much broken. Under his superintendance, the silk-worm industry of the district was completely restored, so much so that the sale of the healthy worms brought in a nett profit of 26,000,000 frs., and this in a place where the previous year, the silk harvest had not been sufficient to pay the cost of healthy eggs. The Emperor was so much impressed by the value of the work over which Pasteur had expended the energy of five years of his life, that in July, 1870, he nominated him a Senator for life, but, owing to the immediate out-break of the Franco-Prussian war, this nomination was never even gazetted.

After the war was over, and whilst the Commune was raging in

Paris, we find Pasteur in the laboratory of his friend and pupil Duclaix, at Clermont-Ferrand, stricken down with disease and overwhelmed by the disasters of the campaign, but still working hard. Here Pasteur extended his researches, commenced many years before on wine, to the disease of beer. Strange as it sounds, beer is much more delicate than wine, much more subject to disease; but this is easily explained when we recollect that it is much less acid and less alcoholic than wine, and that it contains more sugar, and so affords a better home for micro-organisms. It is impossible to consider with any degree of detail Pasteur's work in this field. He shewed the paramount importance of pure yeast, and traced the origin of many of the diseases of beer back to micro-organisms which prey upon the yeast cells. To detect these he introduced the microscope into the brewing room, and to exclude them he emphasized the necessity of absolute cleanness in the fermenting rooms, &c. In a word, he elevated brewing from the rank of an art to that of a science.

Toward the close of his exhaustive work "On Beer and its Diseases," Pasteur had written these words, "The ætiology of contagious diseases is on the eve of having unexpected light shed upon it." In spite of the conviction expressed in these words, he hesitated long before throwing himself into those studies which have rendered his name a household word throughout the civilized world. He was not a physician or a surgeon, not even a veterinary doctor, and he hesitated at first to invade the domain of others.

Overcoming his hesitation, he commenced his researches on contagious diseases, by investigating the causes of that terrible disease known as anthrax, or splenic fever. This disease is a most widely-spread one; it attacks almost all cattle, most rodents take it readily, rabbits and guinea pigs dying forty-eight hours after inoculation; rats, however, are infected with difficulty, whilst pigs, dogs, and cats are comparatively insusceptible. Amongst man, especially amongst those who handle cattle or their hides, it is not uncommon, appearing under the name "malignant pustule," or "woolsorters disease."

As long ago as 1850, the bacterium which caused this disease *Bacillus anthracis*, had been observed by Davaine and Rayer, in the blood of animals which had died of anthrax. But this isolated observation was forgotten for thirteen years, until in 1863, Davaine's attention being roused by Pasteur researches, he renewed his observation and pronounced the bacillus to be the cause of the disease. This view met with much opposition, it being as usual, maintained by his critics that the bacterium was the effect and not the cause of the disease. The subject remained in this unsettled condition for another period of thirteen years, when Koch, at that time a young physician living in the neighbourhood of Breslau, published a complete account of the life, history, and distribution of the Anthrax bacillus, and effectually removed all doubt as to its being the cause of the disease. Koch also showed that under certain conditions the bacillus breaks up into spores, which have the power of resisting a degree of heat which would prove fatal to the bacillus itself; he further succeeded in making artificial cultures of the germ in nutrient jellies and broths. The greater resistive powers of the spores to heat had not escaped the attention of Pasteur, who was also working at the bacterium of anthrax, and in connection with this we read of an experiment which gives a wonderful insight into his inductive method of reasoning. It was a well-known fact, that although anthrax passes readily from one kind of animal to another, from quadruped to man, and back again, it never attacks birds. Experiment had shown that a temperature of 44°C. is prohibitive to the multiplication of the germ; now birds have the warmest blood of all vertebrates, the temperature of their circulating medium being as high as 42°C. The bacillus then, when in the body of a fowl, is at a temperature closely bordering on the prohibitive one, and further, being an ærobiotic micro-organism, it is handicapped by having to wrest its oxygen from the blood corpuscles. Under these circumstances it does not thrive, and the fowl escapes a terrible disease.

Now Pasteur said to himself, if the above reasoning be true, and we take a fowl and keep it under such conditions that the temperature of its blood is lowered, it ought, when inoculated, to take the disease. He therefore lowered the temperature of a fowl to 37°C. or 38°C. by placing its feet in cold water, and then inoculated it. Within twenty-four hours it had died of anthrax. He corroborated this experiment, by chilling another fowl, inoculating it and allowing the fever to come to a head. Then he hurried it into a warm chamber, and restored its normal temperature by wrapping it in cotton wool.

In a few hours the returning heat got the better of the bacillus, and the fowl was soon restored to perfect health.

Before considering the methods by means of which Pasteur has succeeded in preventing the outbreak of this disease, we must consider the similar disease of chicken cholera. Although fowls enjoy an immunity from anthrax, owing to the high temperature of their blood, they are very subject to a disease, also caused by a bacterium, known as chicken cholera Bacteria swarm in the bodies of fowls who have died of this disease, and one drop of the blood of such a fowl is sufficient to cause death if injected into a healthy one, they can also be propagated through the alimentary canal, and this often leads to the poultry yards, throughout a large area, being exterminated.

Whilst studying the bacteria of this disease Pasteur made his great discovery of the attenuated virus. It had long been known that an attack of an infectious disease renders the patient proof against another attack, at any rate for some time. Before Jenner's discovery of vaccination, it was not uncommon to inoculate healthy people from mild cases of small pox, in the hope that they would take the disease slightly and thus acquire immunity for the future. Jenner's great discovery substituted another mild disease for the inoculated small pox, but one which proved equally preventive. The discovery of vaccination was, however, an isolated one, and but little understood. Pasteur's great discovery of the method of attenuating virus was a generalization which included Jenner's vaccination as one only of a large series of protective inoculations, which promise in the future to save humanity from many of the most infectious epidemics.

The method of growing the disease-producing germs in pure cultivations has been mentioned above; it consists in sowing the germs in nutrient broths or jellies, under such conditions that only pure air is admitted to them, and under these conditions the germs will live for years. Pasteur discovered that if these cultures were exposed to certain temperatures, the germs gradually lose their virulence, and their power of reproducing disease grows gradually less until it entirely disappears. This he proved first in the case of the germs producing chicken cholera. A fowl was inoculated or vaccinated with the weakened or attenuated virus; it became slightly indisposed but soon recovered. It was then inoculated with the unattenuated virus, and at the same time a similar dose was injected into an unvaccinated fowl. The former escaped without any ill effect, the latter died of chicken cholera. The success of this treatment is shown by the fact that by inoculating fowls with the attenuated virus, Pasteur has succeeded in reducing the death rate of the poultry yards over a large area of France from 10 per cent. to 1 per cent.

Pasteur next applied this discovery to the anthrax bacillus mentioned above. This disease is happily not common in this country, but it is widely spread over all Europe, and very prevalent amongst the herds of cattle wandering over the pampas of South America. In Egypt it is well known, and is regarded there as the direct descendant of one of the plagues of Pharaoh. As usual Pasteur worked with indefatigable ardour and great directness of purpose, and he was soon in a position to state that the attenuation of chicken cholera was not an isolated occurrence, but he had succeeded in doing the same with the anthrax bacillus, and had thus placed a second contagious disease under control. This attenuated virus or vaccine has been the means of saving thousands of cattle, and consequently lessening the danger of giving woolsorters' disease to knackers, drovers, tanners, &c., to a corresponding degree. Pasteur overcame the objections of the agriculturalist, always so difficult to convince, to his method, by an experiment on a large scale. Out of a flock of 50 sheep, 25 were vaccinated, and then every member of the flock was inoculated with strong virus. The vaccinated sheep suffered no inconvenience, the others died of anthrax. The unerring way in which Pasteur was able to foretell the result of such an experiment as the foregoing, helped him immensely in struggling with the ignorance of the French farmer. Since the discovery of this method of vaccinating cattle, nearly 2,000,000 sheep and 100,000 oxen have been protected, the number last year being 269,599 sheep and 34,464 oxen ; and now the Insurance Companies in France insist on the preventive measure being taken before they will insure oxen or sheep.

There are two more points in reference to this terrible disease which must be briefly referred to, one is that the power of the vaccine to grant immunity from the infection does not last very long, probably not more than a year at the most, at the end of which time the cattle must be re-vaccinated. This is, however, not such a drawback as it at first seems. The life of a sheep, born as it is, only to become mutton, is a short one, and the re-vaccination is not a very troublesome operation.

The next point is a debatable one. When an animal dies of anthrax, the usual way to dispose of its body is to bury it. Pasteur claims to have shown that in such cases of earth to earth burial, the germs infect the ground and are brought to the surface by the action of earthworms, and cattle grazing in a field where such a body is buried become infected with the disease, and a new out-break occurs. These statements are not confirmed by other observers, but inasmuch as positive evidence in a case of this kind must be of more value than negative, animals dying of anthrax should be cremated and not buried.

I must now hurry on, to say a few words about Pasteur's latest work, which more than any other has brought his name conspicuously before the public. The disease of Hydrophobia has been known to exist since the days of Aristotle, it has never been very common, breaking out from time to time in certain places and then almost disappearing again, but unfortunately what it lacks in frequency it more than makes up in intensity. It has always been regarded as incurable, and the knowledge that if it once breaks out the patient must necessarily die a most painful and horrible death, has affected the popular imagination, and few diseases have centred round them such a mass of fabulous stories and proverbial lore.

Hydrophobia, or as it is better to call it, Rabies, reserving the longer term for one of the symptoms of the malady, is a specific infectious disease, which attacks most commonly the canine race, but occurs also in cats, horses, mules, sheep, swine, goats, and man. Only in England has it been known to occur amongst deer. Two years ago there was an outbreak in Richmond Park which caused the death of 264 deer, and this summer, rabies made its appearance in the Marquis of Bristol's Park at Ickworth in Suffolk, and carried off 450 deer out of a herd of between 600 and 700 animals. The occurrence of rabies amongst deer in this country alone, is probably connected with the fact that we are the only people who keep large numbers of these animals in a semi-wild condition, confined within our parks.

It has been fairly well proved that rabies never originates *de novo*, but is invariably passed on from one animal to another, the inoculation being either caused by a bite, or more rarely by the saliva of a rabid animal coming in contact with an open wound or a raw surface on another. It never breaks out in a country unless introduced, and is to the present day unknown in Norway and Lapland, where there are great numbers of dogs; in many of the Pacific Islands, and throughout the great continent of Australia. This being the case, "it is easy to understand that simple police measures will suffice to stamp out this horrible disease, more especially in insular countries like England and Ireland. Two or three years would perhaps be enough to eradicate it, if owners were compelled to muzzle their dogs or lead them by a string when in the streets. The destruction of all wolves in the United Kingdom was a far more difficult task, and yet it was successfully accomplished."

This statement is no gratuitous opinion, but it is the deliberate verdict of Pasteur, who has spent the last nine years in studying rabies, and who has further devoted a large portion of his lifetime to save animals from disease and suffering. I am glad to say that this opinion has been ratified by the verdict of a crowded meeting held last week at the Westminster Palace Hotel.

It had long been known that the poison of rabies existed in the saliva of mad dogs, and that their bite communicated the disease, it was also known that the period of incubation, that is the time which elapsed between the bite and the outbreak of the disease, varied from some days to several months. This represented the amount of accurate knowledge about Rabies when Pasteur in 1880 commenced to study its symptoms and causes.

One of the first discoveries he made was that the virus attacked the nerve centres, that the seat of the disorder was the brain, more particularly in that part known as the Medulla Oblongata, at the junction of the brain with the spinal cord. He was further able, after a good many experiments, to produce the disease, without failure, in a given number of days, the period of incubation in a rabbit being shortened and fixed at six or seven days. This in itself was an immense advance; to show where the disease lay and to be able to produce it at will and within a given time, were great steps toward the discovery of a preventive treatment. The next problem which arose was, could the virus be attenuated? Here the difficulty was of a different character to that which existed in the case of anthrax. In the latter disease the microbe could be isolated, and artificially cultivated in test tubes, but in the case of Rabies no method has yet been found by which the virus can be grown outside the body. Furthermore, the microbe of the disease has not yet been found, and this fact has been used by the opponents of Pasteur in their efforts to discredit his treatment; but if we remember how minute these organisms are, and how each kind requires a special mode of preparing and staining in order to make them visible, we shall not be surprised that hitherto this particular micro-organism has eluded the search of the most experienced microscopists. Its manifestations however are so clear and so analagous to those of other known microbes that we are justified in believing in its existence, just as we believe in the presence of a star which no one has ever seen, but whose existence and position has been calculated by astronomers from the perturbations it excites amongst neighbouring heavenly bodies.

But this is not all, very recently it has been shown that in the case of diseases caused by micro-organisms, it is not the germs themselves which directly cause death, but that they set up changes in the tissue, which result in the formation of certain poisons, and it is these poisons which bring about the decease of the patient. Within the last few months it has been found possible to isolate some of these poisons. Dr. Roux, one of Pasteur's assistant's, has succeeded in so isolating the poison produced by the diphtheria baccillus, and by inoculating with this he can produce death accompanied with all the symptoms of diphtheria, minus only the characteristic diphtheritic membrane on the throat, which is permeated by masses of the baccilli. Even more recently the poison of anthrax has been isolated by a young Cambridge student working in Koch's laboratory in Berlin. The existence of these poisons helps us to understand the rationale of Pasteur's method of preventative inoculation for Hydrophobia.

He was unable to procure an attenuated virus in the same way as he did in the case of chicken cholera and anthrax, because as I said just now, it has not been found possible to make a pure cultivation of the virus and then weaken it. So that he cast about for some other method, and the one he eventually hit upon was this: by successive inoculations he had supplied himself with a virus of known strength, that is, one which would kill a rabbit without fail on the 10th day. If the spinal cord of such a rabbit is kept at a temperature of 25° C. for 13 or 14 days, the bacteria in it being exceedingly susceptible to heat and drying, have disappeared, that is have died. But a little of the poison is left in the cord. The amount of poison is not enough to produce rabies, if inoculated, but it has a slight vaccinating effect. If a similar cord be kept 11 or 12 days, it will have more poison, and a few bacteria, and so the strength of the virus increases until it reaches a maximum in the fresh cord. Now the theory of vaccination rests on the fact that mild doses of a virus will give immunity to stronger doses, if injected first. The small amount of poison contained in the 14 days' cord will cause no damage when injected into the patient, and will prevent not only any damage being caused by the larger amount of poison contained in the 12 days' cord, but will also grant immunity from harm being brought about by the presence of the few bacteria which exist in a cord of that date. In like manner the 12th days' cord will render harmless the virus of the 10th, and the 10th of the 8th, and so on, until emulsions of the fresh cord can be injected without any harm ensuing, and yet the virus in them is potent enough to give us all rabies if a single drop be injected into our bodies without the milder doses coming first.

Pasteur proved the value of his methods by experiments on rabbits and dogs, and as evidence of the lasting effect of his vaccination, I may mention that there are now living in the Laboratory at Paris five dogs which were vaccinated in 1884, and then bitten by a rabid dog, these dogs were again bitten in 1888 by another mad dog and suffered no harm, whereas three out of five unvaccinated dogs bitten by the same rabid animal, died of hydrophobia. This experiment shows that the immunity granted by this method of vaccination lasts at least four years, probably much longer.

Hitherto we have only considered the case of the prevention of Rabies, animals were vaccinated and then bitten by mad dogs, or the virus injected, and the disease did not break out. This, although a grand advance, does not help man much, the chances of being bitten by a mad dog being too small to justify us in undergoing a preventive vaccination, such as we submit to in the case of small pox. This being the case, the question arose, would the vaccine be of any use if injected after the bite? Pasteur showed that under certain conditions it would. And to explain these I must once again refer to the chemical poison produced by the bacillus. The bacteria from the mad dog would take some days, in rare cases some months, before it formed sufficient poison to act on the brain and produce the symptoms of hydrophobia; if in the meantime sufficient vaccine poison can be injected, the former cannot be produced, so that the cure resolves itself into a race between the bacteria and the inoculator. If the injected matter contained only bacteria, the virus from the mad dog would win, because it has a few hours, sometimes a few days start, but the presence of the chemical poison in the vaccine turns the odds in favour of the doctor. The existence of this contest emphasizes the importance of losing no time after being bitten in presenting oneself for the preventive inoculations, it also serves to explain the fact that bites on the head or neck are much more dangerous than those on the limbs. The path by which the virus travels to the brain is not very certainly known, but if, as there is some reason to believe, it lies along the nerves, it is easy to see that the virus would reach its goal and produce its fatal effects more quickly if it entered at the head than if it first passed into the body by some remoter organ.

Before leaving this part of the subject, I would like to impress upon you that the treatment for rabies is so far unique, that it is the only disease which has been successfully treated by vaccination, after the entrance of the poisonous virus, but there are indications, however, that this may one day be the case in other infectious diseases.

It required no small amount of courage on Pasteur's part to apply the treatment which he had tested and found adequate with the lower animals, to his fellow creatures. However, in July, 1885, he dared to do this, and inoculated a boy named Meister, who had been terribly bitten by a mad animal. The inoculation was thoroughly successful. His second patient is commemorated by a bronze statue which ornaments the front of the Pasteur Institute in Paris: the statue represents in the most realistic way the struggle between a shepherd boy, armed only with his wooden sabot, and a mad dog. The hero of the group was successful in the combat, but was terribly bitten during its progress; he was the second patient submitted to the preventive treatment at Paris.

I do not propose to consider in detail any other cases, or to weary you with lengthy statistics. In justice to the treatment, I must, however, mention a few figures. The most careful enquiries in the matter, show that of every hundred persons bitten by dogs known to be mad, from 15 to 20 will die a most painful and horrible death. Pasteur, by his treatment, has succeeded in reducing this percentage of deaths to something under one. The diagram below, taken from Dr. Armand Ruffer's article on "The Prevention of Hydrophobia by M. Pasteur," * gives the percentages of deaths amongst the patients treated in his Institute for the year 1888.

TABLE I.—*January 1st to December 31st*, 1888.

	A.	B.	C.
Number of persons inoculated.	1626	1371	255
Mortality *a.*	1·16 per cent.	1·31 per cent.	0·39 per cent.
,, *b.*	0·79 ,,	0·94 ,,	Nil.
,, *c.*	0·55 ,,	0·65 ,,	Nil.

TABLE II.—*Patients bitten on the Face or Head, and having undergone M. Pasteur's Treatment during the year* 1888.

	A.	B.	C.
Number of persons inoculated.	123	109	14
Mortality *a.*	7·33 per cent.	8·25 per cent.	Nil.
,, *b.*	4·80 ,,	5·41 ,,	Nil.
,, *c.*	2·44 ,,	2·75 ,,	Nil.

Explanations.—Column A. in each table includes all the cases inoculated at the Pasteur Institute during the year. Column B. includes only patients bitten by animals proved to be rabid at the time they inflicted the wound. (This corresponds to columns A. and B. in M. Pasteur's own tables.) Column C. gives the number of patients bitten by animals which, though presumably rabid, could not be proved to have been so.

Mortality *a.*=Total mortality, including patients dying during the progress of treatment. Mortality *b.*=Mortality after those who died during treatment have been excluded. Mortality *c.*=Mortality after those who died within fourteen days after the completion of treatment have been excluded. *The lowest mortality in people bitten by rabid animals and not inoculated amounts to 15 per cent. at least.*

Taking the present year from Nov. 1st, 1888, to Nov. 1st, 1889, we find that out of 1830 patients, only 11 have died, giving an

* "The British Medical Journal," No. 1499, Sept. 21st, 1889.

average of only 0·6 per hundred, and if we deduct from these those who died during the treatment, or immediately after it, the percentage is reduced to 0·38, lower than that of the previous year. As a control experiment, I will mention that in 1887, 350 people were bitten in Paris by rabid animals, of these 306 were inoculated by Pasteur, and 3 of them died, giving an average mortality of 0·97 per cent., the remaining 44 took their chance, and 7 of them died, giving a mortality of 15·9 per cent.

In conclusion, I would particularly draw your attention to the necessity of having the percentages of mortality before you whilst considering the efficacy of any particular method of treatment, preventive or otherwise. The walls of this town are placarded with a most carefully compiled list of names of those who have unfortunately died during or after Pasteur's inoculations. The placard, however, omits to mention that but for the treatment the names on the list must have been increased fifteenfold. Pasteur has suffered much from such misrepresentations, those in whom the love for dogs and cats has superseded their love for their neighbours have pursued him with that bitterness which is so frequently evinced when philozoic sentiment overpowers the philanthropic feeling of the community. He pays, however, but little heed to the attacks which are directed against him; a man who has spent the better part of his life in working for the good of the lower animals, and the remainder in alleviating the diseases of his fellow men, can well afford to consider himself above criticism in these respects, but the consideration of a life so spent helps us to realise that there was some truth in the old Arabian proverb, "the ink of science is more precious than the blood of the martyrs."

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